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ABSTRACT

This document submits that the existence of objective knowledge and the possibility of communicating it by means of language have traditionally been taken for granted by educators. This paper presents a brief outline of an alternative theory of knowing that takes into account the thinking organism's cognitive isolation from "reality." This orientation was proposed by Vico at the beginning of the 18th century, disregarded for 200 years, and then propounded independently by Piaget as a developmentally grounded constructivist epistemology. The paper focuses specifically on the "adaptive" aspect of communication, and the subjective perspective on social interaction. Identified are some of the consequences a shift of epistemological presuppositions might have on the practice of teaching science. (TW)

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Cognition, Construction of Knowledge, and Teaching*

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Abstract

The existence of objective knowledge and the possibility of communicating it by means of language have traditionally been taken for granted by educators. Recent developments in the philosophy of science and the historical study of scientific accomplishments have deprived these presuppositions of their former plausibility. Sooner or later, this must have an effect on the teaching of science. In this paper I am presenting a brief outline of an alternative theory of knowing that takes into account the thinking organism's cognitive isolation from "reality". This orientation was proposed by Vico at the beginning of the 18th century, disregarded for two hundred years, and then propounded independently by Piaget as a developmentally grounded constructivist epistemology. The paper focuses specifically on the "adaptive" function of cognition, Piaget's scheme theory, the process of communication, and the subjective perspective on social interaction. In the concluding section it then suggests some of the consequences the shift of epistemological presuppositions might have for the practice of teaching.

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Cognition, Construction of Knowledge, and Teaching

Ernst von Glasersfeld

> The only truly ubiquitous factors in cognitive developments--be it in the history of science or in the ontogeny of mind--are of a functional, not a structural kind.
>
> Piaget & Garcia, 1983, p.38

During the last three decades faith in objective scientific knowledge, a faith that formerly served as the unquestioned basis for most of the teaching in schools and academia, has been disrupted by unsettling movements in the very discipline of philosophy of science. Though the roots of the subversion go back a good deal further, the trouble was brought to the awareness of a wider public by the publication of Kuhn's *The Structure of Scientific Revolutions*. There, undisguised and for everyone to read, was the explicit statement that

> ... research in parts of philosophy, psychology, linguistics, and even art history, all converge to suggest that the traditional epistemological paradigm is somehow askew. That failure to fit is also made increasingly apparent by the historical study of science ... . None of these crisis-promoting subjects has yet produced a viable alternate to the traditional epistemological paradigm, but they do begin to suggest what some of that paradigm's characteristics will be. (Kuhn, 1970, p.121)

While the troubles of the "traditional epistemological paradigm" have shown no sign of subsiding in the years since Kuhn's publication, one could not honestly say that any substitute has been generally accepted. In most Departments of Psychology and Schools of Education, teaching continues as though nothing had happened and the quest for immutable objective Truths were as promising as ever. For some of us, however, a different view of knowledge ***has*** emerged, not as a new invention but rather as the result of pursuing suggestions made by much earlier dissidents. This view differs from the old one in that it deliberately discards the notion that knowledge could or should be a representation of an observer-independent world-in-itself and replaces it with the demand that the conceptual constructs we call knowledge be ***viable*** in the experiential world of the knowing subject.

Ludwig Fleck, whose monograph of 1935 Kuhn acknowledged as a forerunner, wrote an earlier article in 1929 that went virtually unnoticed and that already contained much that presages what the Young Turks have been proposing in recent years:

> The content of our knowledge must be considered the free creation of our culture. It resembles a traditional myth (Fleck 1929, p. 425).
> Every thinking individual, insofar as it is a member of some society, has its own reality according to which and in which it lives (p.426).
> Not only the ways and means of problem solutions are subject to the scientific style, but also, and to an even greater extent, the choice of problems (p. 427).

In his monograph, Fleck then cites Jakob von Uexküll (1928) as a fellow proponent of the notion of subjective realities, but criticizes him for not being radical enough. In retrospect, one might conjecture that Fleck would have agreed more fully with von Uexküll's later elaboration of the biological organisms' self-generated environments. In any case, it is this ***construction*** of the individual's subjective reality which, I want to suggest in this paper, should be of interest to practitioners and researchers in education and, in particular, to the teachers of science.

The notion of cognitive construction was adopted in our century by Mark Baldwin and then extensively elaborated by Jean Piaget. Piaget's ***constuctivist*** theory of cognitive development and cognition, to which I shall return later, had, unbeknownst to him, a striking forerunner in the Neapolitan philosopher Giambattista Vico. Vico's epistemological treatise (1710) was written in Latin and remained almost unknown. Yet no present-day constructivist can afford to ignore it, because the way Vico formulated certain key ideas and the way they were briefly discussed at the time is, if anything, more relevant today then it was then.

The Roots of Constructivism

The anonymous critic who, in 1711, reviewed Vico's first exposition of a thoroughly constructivist epistemology expressed a minor and a major complaint. The first--with which any modern reader might agree--was that Vico's treatise is so full of novel ideas that a summary would turn out to be almost as long as the work itself (e.g., the introduction of developmental stages and the incommensurability of ideas at different historical or individual stages, the origin of conceptual certainty as a result of abstraction and formalization, the role of language in the shaping of concepts). The reviewer's second objection, however, is more relevant to my purpose here, because it clearly brings out the problem constructivists run into, from Vico's days right down to our own.

Vico's treatise *De antiquissima Italorum sapientia* (1710), the Venetian reviewer says, is likely to give the reader "an idea and a sample of the author's metaphysics rather than to prove it." By ***proof***, the 18th-century reviewer intended very much the same as so many writers seem to intend today, namely a solid demonstration that what is asserted is ***true*** of the real world. This conventional demand cannot be satisfied by Vico or any proponent of a radically

constructivist theory of knowing: one cannot do the very thing one claims to be impossible. To request a demonstration of ***Truth*** from a radical constructivist shows a fundamental misunderstanding of the author's explicit intention to operate with a different conception of knowledge and of its relation to the "real" world.

One of Vico's basic ideas was that epistemic agents can ***know*** nothing but the cognitive structures they themselves have put together. He expressed this in many ways, and the most striking is perhaps: *"God is the artificer of Nature, man the god of artifacts."* Over and over he stresses that "to know" means ***to know how to make***. He substantiates this by saying that one knows a thing only when one can tell what components it consists of. Consequently, God alone can know the ***real*** world, because He knows how and of what He has created it. In contrast, the human knower can know only what the human knower has constructed.

For constructivists, therefore, the word ***knowledge*** refers to a commodity that is radically different from the objective representation of an observer-independent world which the mainstream of the Western philosophical tradition has been looking for.[1] Instead, ***knowledge*** refers to conceptual structures that epistemic agents, given the range of present experience within their tradition of thought and language, consider ***viable***.

Richard Rorty, in his Introduction to *Consequences of Pragmatism*, announces this shift of focus in terms that fit the constructivist's position just as well as the pragmatist's:

> He (the pragmatist) drops the notion of truth as correspondence with reality altogether, and says that modern science does not enable us to cope because it corresponds, it just enables us to cope. (Rorty 1982, p.XVII)

Constructivism *is* a form of pragmatism and shares with it the attitude towards knowledge and truth; and no less than pragmatism does it go against "the common urge to escape the vocabulary and practices of one's own time and find something ahistorical and necessary to cling to" (Rorty 1982, p. 165).

The anonymous reviewer's complaint that Vico did not ***prove*** his thesis, reproaches Vico for not having claimed for his "metaphysics" (which was actually a theory of knowing) the correspondence with an ahistorical ontic world ***as God might know it***. But this notion of correspondence was precisely what Vico--like the pragmatists--intended to drop.

Present-day constructivists, however, if pressed for corroboration rather than proof in the traditional sense, have an advantage over Vico. They can claim ***compatibility*** with scientific models that enable us to "cope" remarkably well in specific areas of experience. For instance, one might cite the neurophysiology of the brain and quote Hebb's:

> At a certain level of physiological analysis there is no reality but the firing of single neurons (Hebb 1958, p. 461).

This is complemented by von Foerster's (1970) observation that all sensory receptors (i.e. visual, auditory, tactual, etc.) send physically indistinguishable "responses" to the cortex and that, therefore, the "sensory modalitities" can be distinguished only by keeping track of the part of the body from which the responses come, and ***not*** on the basis of "environmental features". Such statements make clear that contemporary neurophysiological models may be compatible with a constructivist theory of knowing but can in no way be integrated with the notion of transduction of "information" from the environment that any realist epistemology demands.

Knowledge as an Adaptive Function

Constructivism differs from pragmatism in its predominant interest in *how* the knowledge that "enables us to cope" is arrived at. The work of Jean Piaget, the most prolific constructivist in our century, can be interpreted as one long struggle to design a model of the generation of viable knowledge. In spite of the fact that Piaget has reiterated innumerable times (cf. 1967a, pp.210ff) that, from his perspective, cognition must be considered an ***adaptive function***, most of his critics argue against him as though he were concerned with the traditional notion of knowledge as correspondence.

This misinterpretation is to some extent due to a misconception about adaptation. The technical sense of the term that Piaget intended comes from the theory of evolution. In that context, ***adaptation*** refers to a state of organisms or species that is characterized by their ability to survive in a given environment. Because the word is often used as a verb (e.g. this or that species *has* adapted to such and such an environment), the impression has been given that adaptation is an evolutionary activity. This is quite misleading. In phylogeny no organism can actively modify its genome and generate characteristics to suit a changed environment. According to the theory of evolution, the modification of genes is always an accident. Indeed, it is these accidental modifications that generate the variations on which natural selection can operate. And nature does ***not***--as even Darwin occasionally slipped into saying (Pittendrigh 1958, p.397)--select "the fittest", it merely lets live those that have the characteristics necessary to cope with their environment and lets die all that have not.

This interpretation of the theory of evolution and its vocabulary is crucial for an adequate understanding of Piaget's theory of cognition. As for Vico, knowledge for Piaget is never (and can never be) a "representation" of the real world. Instead it is the collection of conceptual structures that turn out to be adapted or, as I would say, ***viable*** within the knowing subject's range of experience.

In both, theory of evolution and the constructivist theory of knowing, "viability" is tied to the concept of equilibrium. Equilibrium in evolution indicates the state of an organism or species in which the potential for survival in a given environment is genetically assured. In the sphere of cognition, though indirectly linked to survival, equilibrium refers to a state in which an epistemic agent's cognitive structures have yielded and continue to yield expected results, without bringing to the surface conceptual conflicts or contradictions. In neither case is equilibrium necessarily a static affair, like the equilibrium of a balance beam, but it can be and often is dynamic, as the equilibrium maintained by a cyclist.

To make the Piagetian definition of knowledge plausible, one must immediately take into account (which so many interpreters of Piaget seem to omit) that a human subject's experience always includes the social interaction with other cognizing subjects. This aspect of social interaction is, obviously, of fundamental importance if we want to consider education, that is, any situation in which the actions of a teacher are aimed at generating or modifying the cognitive constructions of a student. But introducing the notion of social interaction, raises a problem for constructivists. If what a cognizing subject knows cannot be anything but what that subject has constructed, it is clear that, from the constructivist perspective, the ***others*** with whom the subject may interact socially cannot be posited as an ontological given. I shall return to this problem as well as to the constructivist approach to education; but first I want to explicate the basis of a Piagetian theory of learning.

The Context of Scheme Theory

Two of the basic concepts of Piaget's theory of cognition are ***assimilation*** and ***accommodation***. Piaget's use of these terms is not quite the same as their common use in ordinary language. Both terms must be understood in the context of his constructivist theory of knowing. Unfortunately, this is what contemporary textbooks in developmental psychology (most of which devote at least a few pages to Piaget) often fail to do. Thus one reads, for instance:

> Assimilation is the process whereby changing elements in the environment become incorporated into the structure of the organism. At the same time, the organism must accommodate its functioning to the nature of what is being assimilated. (Nash 1970, p. 360)

This is not at all what Piaget meant. One reason why assimilation is so often misunderstood is that its use as an explanatory postulate ranges from the unconscious to the deliberate. Another stems from disregarding that Piaget uses that term, as well as "accommodation", within the framework of his theory of schemes. An example may help to clarify his position.

An infant quickly learns that a rattle it was given makes a rewarding noise when it is shaken, and this provides the infant with the ability to generate the noise at will. Piaget sees this as the "construction of a ***scheme***" which, like all schemes, consists of three parts:

(1) Recognition of a certain situation (e.g. the presence of a graspable item with a rounded shape at one end);
(2) association of a specific activity with that kind of item (e.g. picking it up and shaking it);
(3) expectation of a certain result (e.g. the rewarding noise).

It is very likely that this infant, when placed in its high-chair at the dining table, will pick up and shake a graspable item that has a rounded shape at one end. We call that item a spoon and may say that the infant is ***assimilating*** it to its rattling scheme; but from the infant's perspective at that point, the item ***is*** a rattle, because what the infant perceives of it is not what an adult would consider the characteristics of a spoon but just those aspects that fit the rattling scheme.[2]

Shaking the spoon, however, does not produce the result the infant expects: the spoon does not rattle. This generates a perturbation ("disappointment"), and perturbation is one of the conditions that set the stage for cognitive change. In our example it may simply focus the infant's attention on the item in its hand, and this may lead to the perception of some aspect that will enable the infant in the future to recognize spoons as non-rattles. That development would be an ***accommodation***, but obviously a rather modest one. Alternatively, given the situation at the dining table, it is not unlikely that the spoon, being vigorously shaken, will hit the table and produce a different but also very rewarding noise. This, too, will generate a perturbation (we might call it "enchantment") which may lead to a different ***accommodation***, a major one this time, that initiates the "spoon banging scheme" which most parents know only too well.

This simple illustration of scheme theory also shows that the theory involves, on the part of the observer, certain presuppositions about cognizing organisms. The organism is supposed to possess at least the following capabilities[3]:

-- The ability and, beyond that, the tendency to establish recurrences in the flow of experience; this, in turn, entails at least two capabilities,
-- remembering and retrieving (re-presenting) experiences,
-- and the abilty to make comparisons and judgements of similarity and difference;
-- apart from these, there is the presupposition that the organism likes certain experiences better than others, which is to say, it has some elementary values.

The first three of these are indispensable in any theory of learning. Even the parsimonious models of classical and operant conditioning could not do without them. As to the fourth, the assumption of elementary values, it was explicitly embodied in Thorndikes ***Law of Effect***: "Other things being equal, connections grow stronger if they issue in satisfying states of affairs" (Thorndike 1931/1966, p.101). It remained implicit in psychological learning theories since Thorndike, but the subjectivity of what is "satisfying" was more or less deliberately obscured by behaviorists through the use of the more objective sounding term "reinforcement".

The learning theory that emerges from Piaget's work can be summarized by saying that cognitive change and ***learning*** take place when a scheme, instead of producing the expected result, leads to perturbation, and perturbation, in turn, leads to accommodation that establishes a new equilibrium. Learning and the knowledge it creates, thus, are explicitly instrumental. But here, again, it is crucial not to be rash and too simplistic in interpreting Piaget. His theory of cognition involves a two-fold instrumentalism. On the ***sensory-motor*** level, action schemes are instrumental in helping organisms to achieve goals in their interaction with their experiential world. On the level of ***reflective abstraction***, however, operative schemes are instrumental in helping organisms achieve a coherent conceptual network that reflects the paths of acting as well as thinking which, at the organisms' present point of experience, have turned out to be viable. The first instrumentality might be called "utilitarian" (the kind philosphers have traditionally scorned). The second, however, is strictly "epistemic". As such, may be of some philosophical interest--above all because it entails a radical shift in the conception of "knowledge", a shift that eliminates the paradoxical conception of Truth that requires a forever unattainable ontological test. The shift that substitutes viability in the experiential world for correspondence with ontological reality applies to knowledge that results from inductive inferences and generalizations. It does not affect deductive inferences in logic and mathematics. In Piaget's view, the certainty of conclusions in these areas pertains to mental operations and not to sensory-motor material (cf. Beth & Piaget 1961; Glasersfeld, 1985*b*).

The Social Component

In connection with the concept of viability, be it "utilitarian" or"epistemic", social interaction plays an important role. Except for animal psychologists, social interaction refers to what goes on among humans and involves language. As a rule it is also treated as essentially different from the interactions human organisms have with other items in their experiential field, because it is more or less tacitly assumed that humans are from the very outset privileged experiential entities. Constructivists have no intention of denying this intuitive human prerogative. But

insofar as their theory of knowing attempts to model the cognitive development that provides the individual organism with *all* the furniture of his or her experiential field, they want to avoid assuming any cognitive structures or categories as innate. Hence, there is the need to hypothesize a model for the conceptual genesis of "others".

On the sensory-motor level, the schemes a developing child builds up and manages to keep viable will come to involve a large variety of "objects". There will be cups and spoons, building blocks and pencils, rag dolls and teddy bears--all seen, manipulated, and familiar as components of diverse action schemes. But there may also be kittens and perhaps a dog. Though the child may at first approach these items with action schemes that assimilate them to dolls or teddy bears, their unexpected reactions will quickly cause novel kinds of perturbation and inevitable accomodations. The most momentous of these accommodations can be roughly characterized by saying that the child will come to ascribe to these somewhat unruly entities certain properties that radically differentiate them from the other familiar objects. Among these properties will be the ability to move on their own, the ability to see and to hear, and eventually also the ability to feel pain. The ascription of these properties arises simply because, without them, the child's interactions with kittens and dogs cannot be turned into even moderately reliable schemes.

A very similar development may lead to the child's construction of schemes that involve still more complex items in her experiential environment, namely the human individuals who, to a much greater extent than other recurrent items of experience, make interaction unavoidable. (As we all remember, in many of these inescapable interactions, the schemes that are developed aim at avoiding unpleasant consequences rather than creating rewarding results.) Here again, in order to develop relatively reliable schemes, the child must impute certain capabilities to the objects of interaction. But now these ascriptions comprise not only perceptual but also cognitive capabilities, and soon these formidable "others" will be seen as intending, making plans, and being both very and not at all predictable in some respects. Indeed, out of the manifold of these frequent but nevertheless special interactions, there eventually emerges the way the developing human individual will think both of "others" and of him- or herself.

This reciprocity is, I believe, precisely what Kant had in mind when he wrote:

> It is manifest that, if one wants to imagine a thinking being, one would have to put oneself in its place and to impute one's own subject to the object one intended to consider ... (Kant 1781, p.223)

My brief account of the conceptual construction of "others" is no doubt a crude and preliminary analysis but it at least opens a possibility of approachng the problem without

the vacuous assumption of innateness. Besides, the Kantian notion that we impute the cognitive capabilities we isolate in ourselves to our conspecifics, leads to an explanation of why it means so much to us to have our experiential reality confirmed by others. The use of a scheme always involves the expectation of a more or less specific result. On the level of reflective abstraction, the expectation can be turned into a prediction. If we impute planning and foresight to others, this means that we also impute to them some of the schemes that have worked well for ourselves. Then, if a particular prediction we have made concerning an action or reaction of an other turns out to be corroborated by what the other does, this adds a second level of viability to our scheme; and this second level of viablity strengthens the experiential reality we have constructed (cf. Glasersfeld 1985a, 1986).

A Perspective on Communication

Although it is not always explicitly acknowledged, the separation of two kinds of instrumentality, which I mentioned above, is not a new one in the field of education. Since the days of Socrates, teachers have known that it is one thing to bring students to acquire certain ways of acting--be it kicking a football, performing a multiplication algorithm, or the reciting of verbal expressions--but quite another to engender understanding. The one enterprise could be called "training", the other "teaching", but educators, who are often better at the first than at the second, do not always want to maintain the distinction. Consequently, the methods for attaining the two goals tend to be confused. In both, communication plays a considerable part, but what is intended by "communication" is not quite the same.

Early studies of communication developed a diagrammatic representation of the process as it appears to an outside observer. Success or failure of a communication event was determined on the basis of the observable behavior of a sender and a receiver. This schema was highly successful in the work of communication engineers (Cherry 1966, p.171). It was also immediately applicable to the behaviorist approach to teaching and learning. The teacher's task, according to that view, consisted largely in providing a set of stimuli and reinforcements apt to condition the student to "emit" behavioral responses considered appropriate by the teacher. Wherever the goal is students' reliable replication of an observable behavior, this method works well. And because there is no place in the behaviorist approach for what we would like to call ***understanding***, it is not surprising that the behavorist training rarely, if ever, produces it.

The technical model of communication (Shannon 1948), however, established one feature of the process that remains important no matter from what orientation one approaches it: The physical signals that travel from one communicator to another--for instance the sounds of speech and the visual patterns of print or writing in linguistic communication--do not actually ***carry*** or ***contain*** what we think of as "meaning".

Instead, they should be considered instructions to select particular meanings from a list which, together with the list of agreed signals, constitutes the "code" of the particular communication system. From this it follows that, if the two lists and the conventional associations that link the items in them are not available to a receiver before the linguistic interaction takes place, the signals will be meaningless for that receiver.

From the constructivist point of view, this feature of communication is of particular interest because it clearly brings out the fact that language users must individually ***construct*** the meaning of words, phrases, sentences, and texts. Needless to say, this semantic construction does not always have to start from scratch. Once a certain amount of vocabulary and combinatorial rules ("syntax") have been built up in interaction with speakers of the particular language, these patterns can be used to lead a learner to form novel combinations and, thus, novel conceptual compounds. But the basic elements out of which an individual's conceptual structures are composed and the relations by means of which they are held together cannot be transferred from one language user to another, let alone from a proficient speaker to an infant. These building blocks must be abstracted from individual experience; and their interpersonal fit, which makes possible what we call communication, can arise only in the course of protracted interaction, through mutual orientation and adaptation (cf. Maturana, 1980).

Though it is often said that normal children acquire their language without noticeable effort, a closer examination shows that the process involved is not as simple as it seems. If, for instance, you want your infant to learn the word "cup", you will go through a routine that parents have used through the ages. You will point to, and then probably pick up and move, an object that satisfies your definition of "cup", and at the same time you will repeatedly utter the word. It is likely that mothers and fathers do this "intuitively", i.e., without a well-formulated theoretical basis. They do it because it usually works. But the fact that it works does not mean that it has to be a simple matter. There are at least three essential steps the child has to make.

The first consists in focusing attention on some specific sensory signals in the manifold of signals which, at every moment, are available within the child's sensory system; the parent's pointing provides a merely approximate and usually quite ambiguous direction for this act.

The second step consists in isolating and coordinating a group of these sensory signals to form a more or less discrete visual item or "thing". The parent's moving the cup greatly aids this process because it accentuates the relevant figure as opposed to the parts of the visual field that are to form the irrelevant ground.[4]

The third step, then, is to associate the isolated visual pattern with the auditory experience produced by the parent's utterances of the word "cup". Again, the child must first isolate the sensory signals that constitute this audi-

tory experience from the background (the manifold auditory signals that are available at the moment); and the parent's repetition of the word obviously enhances the process of isolating the auditory pattern as well as its association with the moving visual pattern.

If this sequence of steps provides an adequate analysis of the initial acquisition of the meaning of the word "cup", it is clear that the child's meaning of that word is made up exclusively of elements which the child abstracts from her own experience. Indeed, anyone who has more or less methodically watched children acquire the use of new words, will have noticed that what they isolate as meanings from their experiences in conjunction with words is often only partially compatible with the meanings the adult speakers of the language take for granted. Thus the child's initial concept of cup often includes the activity of drinking, and sometimes even what is being drunk, e.g., milk. Indeed, it may take quite some time before the continual linguistic and social interaction with other speakers of the language provides occasions for the accommodations that are necessary for the concept the child associates with the word "cup" to become adapted to the adults' extended use of the word, for instance, in the context of golf greens or championships of the sporting kind.

The process of accommodating and tuning the meaning of words and linguistic expressions actually continues for each of us throughout our lives. No matter how long we have spoken a language, there will still be occasions when we realize that, up to that point, we have been using a word in a way that now turns out to be idiosyncratic in some particular respect.

Once we come to see this essential and inescapable subjectivity of linguistic meaning, we can no longer maintain the preconceived notion that words ***convey*** ideas or knowledge; nor can we believe that a listener who apparently "understands" what we say must necessarily have conceptual structures that are identical with ours. Instead, we come to realize that "understanding" is a matter of fit rather than match. Put in the simplest way, to understand what someone has said or written means no less but also no more than to have built up a conceptual structure that, in the given context, appears to be ***compatible*** with the structure the speaker had in mind--and this compatibility, as a rule, manifests itself in no other way than that the receiver says and does nothing that contravenes the speaker's expectations.

Among proficient speakers of a language, the individual's conceptual idiosyncracies rarely surface when the topics of conversation are everyday objects and events. To be considered proficient in a given language requires two things among others: to have available a large enough vocabulary, and to have constructed and sufficiently accommodated and adapted the meanings associated with the words of that vocabulary so that no conceptual discrepancies become apparent in ordinary linguistic interactions. When conversation turns to predominantly abstract matters, it usually does not take

long before conceptual discrepancies become noticeable--even among proficient speakers. The discrepancies generate perturbations in the interactors, and at that point the difficulties become insurmountable if the participants believe that their meanings of the words they have used are ***true representations*** of fixed entities in an objective world apart from any speaker. If, instead, the participants take a constructivist view and assume that a language user's meanings cannot be anything but subjective constructs derived from the speaker's individual experiences, some accommodation and adaptation is usually possible.

From this perspective, the use of language in teaching is far more complicated than it is mostly presumed to be. It cannot be a means of ***transferring*** information or knowledge to the student. As Rorty says: "The activity of uttering sentences is one of the things people do in order to cope with their environment" (1982, p.XVII). In the teacher's case, language becomes a means of constraining and thus orienting the student's conceptual construction.

This inherent and inescapable indeterminacy of linguistic communication is something the best teachers have always known. Independently of any epistemological orientation, they were intuitively aware of the fact that "telling" is not enough, because understanding is not a matter of passively receiving but of actively building up. Yet many who are involved in educational activities continue to act as though it were reasonable to believe that the verbal reiteration of facts and principles must eventually generate the desired understanding on the part of students.

Consequences for Education

The contemporary movements in the philosophy of science converge in the realization that knowledge must not be considered an objective representation of an external observer-independent environment or world. To paraphrase Rorty, the fact that scientific knowledge enables us to cope does not justify the belief that scientific knowledge provides a picture of the world that corresponds to an absolute reality. This stance tends to suggest a return to the sceptics' age-old assertion that we cannot attain certain knowledge about the world. Educators are traditionally averse to accepting such a view, and it is in this regard that pragmatism and constructivism may play a helpful role.

Both these orientations aim at overcoming the sceptics' pessimism, not by contradicting the assertion that objective knowledge is impossible, but by changing the concept of knowledge. Instead of presupposing that knowledge has to be a "representation" of what exists, they posit knowledge as a mapping of what, in the light of human experience, turns out to be feasible. If the theory of knowing that constructivism builds up on this basis were adopted as a working hypothesis, it could bring about some rather profound changes in the general practice of education.

First of all, the distinction of utilitarian and epistemic instrumentality would sharpen the distinction between

training and learning. It would help to separate the acquisition of skills, i.e. patterns of action, from the active construction of viable conceptual networks, i.e. understanding. Hence it would encourage educators to clarify the particular goals they want to attain. Curricula could be designed with more internal coherence and, consequently, would be more effective, once they deliberately separated the task of achieving a certain level of performance in a skill from that of of generating conceptual understanding within a given problem area. There is no question that the old stand-bys "rote learning" and "repeated practice" have their value in training, but it is naive to expect that they must also generate understanding.

The analysis of the process of linguistic communication shows that knowledge cannot simply be transferred by means of words. Verbally explaining a problem does not lead to understanding, unless the concepts the listener has associated with the linguistic components of the explanation are compatible with those the explainer has in mind. Hence it is essential that the teacher have an adequate model of the conceptual network within which the student assimilates what he or she is being told. Without such a model as basis, teaching is likely to remain a hit-or-miss affair.

From the constructivist perspective, "learning" is the product of self-organization. Piaget's dictum "intelligence organizes the world by organizing itself" (1937, p.311) was a challenge to direct the attention of psychologists to the question of how the rational mind organizes experience and to design a model of this process. His scheme theory, as I outlined it above, is an attempt to answer part of that question. It can be summarized in the statement: Knowledge is never acquired passively, because novelty cannot be handled except through assimilation to a cognitive structure the experiencing subject already has. Indeed, the subject does not perceive an experience as novel until it generates a perturbation relative to some expected result. Only at that point the experience may lead to an accommodation and thus to a novel conceptual structure that re-establishes a relative equilibrium. In this context, it is necessary to emphasize that the most frequent source of perturbations for the developing cognitive subject is the interaction with others.[5] This, indeed, is the reason why constructivist teachers of science and mathematics have been promoting "group learning", a practice that lets two or three students discuss approaches to a given problem, with little or no interference from the teacher.

Insofar as learning and knowledge are instrumental in establishing and maintaining the cognizing subject's equilibrium, they are ***adaptive***. Adaptedness, from the constructivist point of view, must be understood as the condition of fit or viability within external and internal constraints. Constraints, however, effect a negative selection. They block and thus determine what does ***not*** fit. They do not prescribe the character of what does not collide with them and therefore slips through. Once this way of thinking takes

root, it changes the teacher's view of "problems" and their solution. No longer would it be possible to cling to the notion that a given task has one solution and only one way of arriving at it. The teacher would come to realize that what he or she presents as a "problem" may be seen differently by the student. Consequently, the student may produce a sensible solution that makes no sense to the teacher. To be then told that it is ***wrong***, is unhelpful and inhibiting (even if the "right" way is explained), because it disregards the effort the student put in. Indeed, such bleak corrections are bound to diminish the student's motivation in future attempts. In contrast, constructivist teachers would tend to explore how students see the problem and why their path towards a solution seemed promising to ***them***. This in turn makes it possible to build up a hypothetical model of the student's conceptual network and to adapt instructional activity so that it provides occasions for accommodations that are actually within the student's reach.

Fleck's statement that I quoted at the beginning, to the effect that the choice of problems is subject to the "style" of the scientific community, applies no less to the individual. The character and structure of what an individual ***sees*** as a "problem" is under all circumstances determined by the conceptual network and the goals of that individual. Once we adopt this as the working hypothesis, the question of motivation becomes accessible from a new direction. We may not have to do this as long as the subject matter we want to teach provides obvious advantages on the level of ***utilitarian*** instrumentality (although even there, it should be clear that what a teacher considers useful will not necessarily be considered useful by students). In the case of topics that pertain to ***epistemic*** instrumentality, the task of fostering motivation is obviously far more difficult. We shall have to make the students perceive the advantage of mastering conceptual models that have a wider range of applicability and success in their experiential world than the ones they have at the moment. More important still, we shall have to create at least some circumstances where the students have the possibility of experiencing the pleasure of finding that a conceptual model they have constructed is, in fact, an adequate and satisfying model in a new situation. Only the experience of such successes and the pleasure they provide can motivate a learner ***intellectually*** for the task of constructing further conceptual models.

It boils down to what Ceccato, the Italian pioneer of conceptual analysis, said in a talk about education years ago:

> The important thing is to show the child (and nothing changes if we substitute "the student") the direction in which to go, to teach him to find his own path, to retrace it, and to continue it. Only in this way will he be able to assume a scientific attitude with which he can approach also the things of the mind (1974, p. 137).

This constitutes a drastic modification of the usual procedure. Yet, where it has been tried, its results are startlingly successful."

Recent developments in the philosophy of science have provided a more adequate way of thinking about how scientists proceed to devise better ways of "coping" with the world of our experience; it should not be surprising that this analysis is applicable also to the process of education. Students may not have the same particular goals that scientists try to attain. But unless we assume that they share, with the inventors and developers of the conceptual models we call science, the goal of constructing a relatively reliable and coherent model of their individual experiential worlds, we cannot lead them to expand their understanding. Memorizing facts and training in rote procedures cannot achieve this.

Good teachers, as I said before, have practised much of what is suggested here, without the benefit of an explicit theory of knowing. Their approach was intuitive and successful, and this exposition will not present anything to change their ways. But by supplying a theoretical foundation that seems compatible with what has worked in the past, constructivism may provide the thousands of less intuitive educators an accessible way to improve their methods of instruction.

FOOTNOTES

1. I am using "objective" in this traditional philosophical sense and would not want it confused with the Humpty Dumpty-like definitions Siegel suggested in his 1982 article. Although he introduces a dichotomy, he does not separate the two most common uses of the word: (a) referring to knowledge that purports to describe the world as it is, and (b) knowledge that purports to be intersubjective.
2. This notion of assimilation seems to be compatible with the view of philosophers of science who maintain that all observation is necessarily "theory-laden".
3. Piaget nowhere lists these presuppositions, but they are implicit in his analysis of conceptual development (cf., for instance, Piaget 1937 and 1967*b*). Another implication of his theory is that none of these presupposed capabilities necessarily require the subject's conscious awareness (see my 1982).
4. Note that, even if the child has coordinated sensory signals to form such a "thing" in the past, each new ***recognition*** involves isolating it in the current experiential field.
5. Piaget was often criticized for not taking into account the social interaction of the child. This, I believe, sprang from the fact that his readers tacitly assumed that the social context in which a child develops affects the child in a way that must be essentially different from the physical one. Instead, when Piaget speaks of adaptation, it never excludes adaptation to others. But although he explicitly acknowledged social and especially linguistic interaction here and there in his writings (e.g. 1967*b*, p.41), he was, as a rule, less interested in the source of perturbations than in the mechanisms for neutralizing them.
6. Teaching methods that are explcitly constructivist have been documented for instance in Clement 1987; Cobb et al. 1987; Confrey 1984; Duckworth, 1987; Lochhead 1983; Steffe 1986; Steffe et al. 1987; Treffers 1987.

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